NOTES ON SOME NATURAL ENEMIES OF THE MOSQUITO IN COLORADO

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In the course of some biological field work in the San Luis valley in Colorado, some predacious enemies of the mosquito were encountered which seem to have escaped notice.† The observations here recorded were made during June and early July 1930, the season of maximum abundance for several species of *Aedes*.

The San Luis valley lies in south central Colorado between the Sangre de Cristo and Culebra mountains on the east and the San Juan mountains of the Continental Divide on the west. The valley has an average elevation of 7500 feet, a north and south extent of 110 miles and an extreme width of about 60 miles. It is a broad, level plain, apparently the bed of an extinct lake, and dry except where irrigated and in the vicinity of the lakes and streams. The Rio Grande is the most important stream in the valley and provides much of the water used in irrigation.

Standing water is limited to the few small lakes scattered over the floor of the valley, to the abandoned ox-bows and sloughs of the Rio Grande and to certain sloughs which derive their water by seepage or overflow from irrigated meadows and fields. Where water stands throughout the year, the natural enemies of the mosquitoes keep them at least partially under control. Dragon flies are present but less numerous than the apparently favorable conditions would lead one to expect. Dytiscid beetle larvæ, notonectids and gerrids are abundant. Among the vertebrate predators may be mentioned several small fishes, a frog, *Rana pipiens*, a cricket frog, *Pseudacris*, a toad, *Bufo*, and the larva of the Tiger salamander, *Ambystoma tigrinum*.

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† Howard, Dyar and Knab in, The Mosquitoes of North and Central America and the West Indies, 1:170, 1912, record the capture, in Panama, of mosquito larvae by flies of the family Dolichopodidae but the species involved were not determined.

Temporary waters offer a more serious problem because of their great extent. On the irrigated native-hay meadows and on fields given over to crops of various kinds where flood irrigation is practiced, water stands from a few days to three or four weeks, creating ideal breeding places for mosquitoes over thousands of acres. In such situations the aquatic enemies of mosquitoes do not become sufficiently well established to be effective. Two of the predators to be mentioned are of interest because they are found not only about the more permanent waters but at pools of the most ephemeral character if these are sheltered from strong winds.

In a small gravel pit which derived its water by seepage or overflow from an adjacent hay meadow, mosquito larvæ were extremely abundant. While collecting at this pool our attention was caught by a number of small, metallic-green flies that drifted lightly over the surface of the water or ran rapidly from one resting place to another. On the surface of the pool, the flies were observed to turn first in one direction then another without discernable movement of the legs or wings, though the turns seemed well directed and often placed them in position above a mosquito larva or pupa at the surface film. Such movements on the part of the flies often caused a precipitous retreat of all the larvæ in the vicinity but seldom quickly enough to prevent one of their number being seized and hoisted squirming above the surface. Usually the captive was devoured on the spot, but at times carried away bodily to some convenient perch. After observing the capture of larvæ in the field, a number of the flies were confined with larvæ and pupæ in a cheese-cloth-covered jar partially filled with water. Here the hunting operations could be observed at short range and we saw several captures. The fly in captivity either glided over the surface or suddenly pounced down upon a larva and continued in its flight to a resting place, the mouthparts of the fly alone being involved in seizing the larva.

On the morning of June 27 we placed twelve larvæ and two pupæ in a jar with two flies. During the day two mosquitoes emerged from their pupal skins and were found dead on the surface of the water and by the following morning nine of the twelve larvæ had been devoured. Two of the remaining larvæ were taken soon after. In the afternoon twenty additional larvæ were provided. During the following day the two flies accounted for the twenty larvæ and were actively hunting for more. On the afternoon of June 30, twenty larvæ and two additional flies were placed in the jar and the four flies captured sixteen larvæ in a period of two and three-quarters hours and the balance before the morning of July 1. During the day (July 1) two of the flies fell into the water and failed to survive the wetting, but the two remaining captured twenty-one larvæ by the morning of July 2. Twenty-five larvæ added in the afternoon of July 2 were reduced in number to ten on July 3 and five on July 4, when the experiment was discontinued. Thus ninety-three larvæ were accounted for in a period of seven days, mostly by two small flies. This record, perhaps, does not compare very favorably with that of certain dytiscid beetle larvæ, individuals of which have been known to kill several hundred larvæ in such a period, but it does add to the known enemies of the mosquito some active little flies that as adults prey on both larvæ and pupæ.

The flies captured while feeding at the surface of the pool were kindly determined for us by Dr. A. O. Johaansen, of Cornell University, as *Dolichopus renidescens* M. and B., *D. nigricauda* M. C. A., *D. appendiculatus* M. C. A., and *D. walkeri* M. C. A. *D. walkeri* was apparently the most abundant species and was the one involved in the laboratory experiment.

The same little pool provided excellent hunting for a considerable number of small lycosid spiders which, like the flies, ran freely over the surface of the water but unlike them did not succumb to a wetting. Often, in fact, they ran down a grass stem to hide below the surface, and thus thwarted our attempts to capture them. The spiders in their hunting quietly anchored themselves by one foot to a floating bit of débris, or sallied forth from the shelter of the marginal vegetation. Again like the flies, the spiders took both larvæ and pupæ and, in addition, adults as they emerged.

Observations in the field were checked by experiments under artificial conditions. During the morning of June 27, twelve larvæ and five pupæ were placed in a half-filled jar with five spiders. At 4 P. M., on June 28, two larvæ and four spiders remained alive, a male spider having proved an acceptable bit to one of the larger females. Ten larvæ were added at 4 P. M., on June 28 and of these nine were eaten by the following evening. By the morning of June 30, the last larva had been devoured and an additional lot of twenty-five larvæ and five pupæ was added. This lot lasted through July 2 when the experiment was brought to a close with the untimely death of two more spiders, victims of the cannibalistic appetites of their fellows. In this experiment four spiders took fifty-seven larvæ and pupæ in the period between June 27 and July 3.

It is not suggested that these spiders limit themselves to a diet of mosquitoes; they merely take advantage of an abundant and easily available food supply. The snares of many web-building spiders capture adult mosquitoes, but these wandering lycosids seek out and take by strategy the larvæ and pupæ in the pools. The spider is *Pardosa sternalis* (Thorell), a strikingly marked species common in the west.

Two deep roadside ditches separated by the width of a country road furnished much material for observation and some food for speculation. The ditch on the one side had an immense number of developing mosquito larvæ and the phyllopod crustacean *Streptocephalus sealii* Ryder,* while that on the other had few of either, but instead supported a number of pond snails. Dytiscid beetle larvæ, dragon-fly nymphs and other well-known mosquito enemies were present in some numbers in both ditches. The presence of the crustaceans suggested that the one ditch must be dry during a part of the year, for these are creatures of the transient pools and many of their kind were to be found on the temporarily flooded hay meadows. But the many aquatic plants and animals pointed to a condition of more or less permanency and we were forced to the conclusion that the ditch was subjected to drying for a short period following

* Kindly determined for us by Edwin P. Creaser of the Museum of Zoology, University of Michigan.

the draining of the adjacent hay meadows. The same aquatic plants and animals were present in the other ditch but the crustaceans were lacking as they were also lacking in all the ponds and sloughs in the vicinity that were obviously permanent in character.

The presence of the pond snails also gave evidence of the persistence of some water in the one ditch throughout the year, just as their absence in the other supported the view that it was subjected to drying. Mosquitoes breed in both permanent and transient waters where conditions are suitable, but here the natural enemies were apparently equally abundant in both. In our search for the agents responsible for the almost complete control of the mosquitoes in the one ditch, the snails appeared as the only possible factors. We were not in a position to decide as to the ability of snails to capture mosquitoes, our knowledge of their feeding habits being limited to the fact that many were plant feeders and a few carnivorous. An accommodating snail at the surface film promptly settled the question by exhibiting a mosquito larva in its mouth. The snail as an active predator excited our interest at once.

Larvæ identified from specimens taken in the ditch where they were abundant were found to belong to mosquitoes of the genus *Aedes* and it might be argued that they were present because the drying of the ditch presented the opportunity for oviposition in the mud of the bottom. The argument is without weight, however, for variation in the height of water in both ditches frequently exposed muddy banks to which adults were attracted in great numbers. Evidence that mosquitoes had deposited their eggs on the banks of the snail inhabited ditch and that the snails could control the developing larvæ was soon forthcoming. In a narrow roadside pool filled by seepage from the main ditch but cut off from it and from the snails by a ridge of earth, young larvæ were found developing by thousands. The ridge had been thrown up by a road scraper and we improved matters somewhat by deepening it and limiting its length, by means of sods, to about six feet. The average width was perhaps fifteen inches. Into this teeming pool, on June 15, we placed sixty snails. On June 18 the larvæ had been greatly reduced in numbers and by the afternoon of the following day only about one-eighth of the original number survived. On June 20 only a few larvæ were to be found and these were concentrated in one shrinking puddle. On June 21 to 22 we did not see the pool and by June 23 the open water had disappeared, due to the lowering of the level in the ditch. No larvæ were to be found on the wet mud, however, and it is reasonable to assume that the snails finished the last of them. The snails were all alive and active when restored to the ditch.

In this experiment the snails alone were responsible for the destruction of the larvæ, other natural enemies being entirely eliminated from consideration. But it should be pointed out that due to the relatively low temperature of the water, development of the larvæ was retarded, giving the snails plenty of time to accomplish their work.

Experiments were conducted under laboratory conditions as follows: At 5 o'clock on the afternoon of June 14, seventeen snails and twelve larvæ were placed together in a cloth-covered jar. By the following morning eleven larvæ had been taken and the twelfth disappeared during the day. At 10:15 P. M., of June 15, twenty-five additional larvæ were placed with the original seventeen snails and by 8 o'clock on the morning of the 16th all had been devoured.

Another lot of fifty larvæ presented to nineteen snails on the afternoon of June 16 had completely disappeared by the afternoon of June 20. Individual snails confined in vials were able each to capture from two to six larvæ in twenty-four hours. The snails not only captured the larvæ, but readily accepted them from the point of the forceps.

No proper estimate of the number of mosquitoes taken by snails under natural conditions could be gained by the laboratory experiments because the majority of the snails promptly applied themselves to the side of the jar and remained without moving through the period of confinement. A few more active individuals were therefore entirely responsible for the destruction. After a few days these too went into retirement and could be induced to eat only by scraping them from their positions.

The snails in their feeding cruised slowly about over the aquatic vegetation or clung, inverted, to the surface film. Forced to the surface to breathe, the mosquito larvæ and pupæ continually bumped into the snails and when contact was made with the fleshy parts, they were promptly seized. The snail would even twist and bend itself to seize a larvæ not in position near its mouth. For an animal endowed with such a reputation for slowness, the movements were surprisingly rapid. Viewed from above, the snail when cruising the surface film, could be seen continually opening and closing its mouth, exhibiting an oval opening entirely adequate to accommodate the largest larva.

Having determined that the snails were actively killing larvæ and pupæ of mosquitoes and that they were apparently responsible for the almost entire absence of them in the roadside ditch, we directed our attention to other ponds and pools which were obviously of a permanent character. In every instance where snails were abundant, mosquito larvæ were so few in numbers as to be negligible.

The snail is *Lymnaea palustris* (Muller), widely distributed in Europe and North America and common in many localities. It was determined for us by Dr. Henry A. Pilsbry of the Academy of Natural Sciences of Philadelphia.